LATEST RESULTS OF THE EDELWEISS EXPERIMENT

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The Edelweiss experiment is a direct detection Dark Matter Search, under the form of WIMPs. It uses heat and ionization Ge cryogenic detectors.We present the latest results obtained by the experiment with three new 320 g bolometers. At present, Edelweiss I is the most sensitive experiment for all WIMP masses compatible with accelerator constraints ($M_{WIMP} > 30$ GeV).We also briefly describe the status of the second stage Edelweiss-II involving initially 10 kg of detectors and aiming a gain of two orders of magnitude in sensitivity.

1 Introduction

Recent cosmological observations [2,3] of the CMB show that the main part of the matter in our Universe is dark and non baryonic. If non baryonic Dark Matter is made of particles, they must be stable, neutral and massive : WIMPs (Weakly Interactive Masssive Particles). In the MSSM (Minimal Supersymmetric Standard Model) framework, the WIMP could be the LSP (Lightest Supersymmetric Particle) called neutralino. It has a mass between few tens and few hundreds of GeV/c^2, and a scattering cross section with a nucleon below 10^{-6} pb.
There are two methods to detect non baryonic Dark Matter under the form of WIMPs : direct, looking for interactions in a detector, and indirect, looking for annihilation products of WIMPs (for a complete review of WIMPs and neutralino Dark Matter, see [4]).
The Edelweiss experiment is dedicated to the direct detection like other experiments (DAMA [5],CDMS [6], ZEPLIN [7], CRESST [8]).

2 The Edelweiss experiment

2.1 Direct detection

In this technique, a WIMP is detected by measuring the nuclear recoil produced by its elastic interaction with an ordinary matter target.
The background consists of two different contributions : neutrons that produce nuclear recoils like WIMPs, and electrons or gammas that induce electron recoils in the target.
The WIMP properties from the most optimistic SUSY models lead to strong constraints on experiments. Indeed calculations predict a deposited energy typically below 100 keV and an interaction rate with ordinary matter below 1 evt/kg/day, requiring experiments with a very low background and large detector masses.

2.2 The experimental setup

The Edelweiss experiment, described elsewhere [9,10], is located at the LSM (french acronym for Modane Underground Laboratory) adjacent to the Frejus tunnel connecting France and Italy. About 1700 m of rock protect the experiment from radioactive background generated by cosmic rays. In the laboratory, the muon flux is reduced by a factor 2×10^6 compared to the flux at sea level. The neutron flux from the rock radioactivity has been measured [11,12] to be $\sim 1.6 \times 10^{-6}$ cm^2.s^{-1}. The experiment is surrounded by passive shielding made of paraffin (30 cm), lead (15 cm) and copper (10 cm).
The Edelweiss experiment used cryogenic Ge bolometers described in more details in [13,14]. They have a cylindrical geometry. To improve electric field geometry in the crystal, their edges are beveled at an angle of 45 degrees. One of the main characteristics of these detectors is the two simultaneous measurement of ionization and heat. The ionization signal is collected by aluminum electrodes on each side of the crystal. The tiny rise in temperature is measured by a NTD heat sensor glued onto one electrode. Moreover some detectors were equipped with an amorphous layer (in Ge or Si) to improve charge collection efficiency for near surface events [15].
On one side, the electrode is segmented in order to define a central fiducial volume and a guard ring. Most of the radioactivity due to the detector environment is collected on the latter part of the detector. The fiducial inner volume, defined as $\geq 75\%$ of the charge collected on the central electrode, corresponds to 57 % of the total detector volume [14].
Since January 2002, three 320 g detectors have been simultaneously operated in a dilution cryostat working at a regulated temperature of 17 mK. To decrease the background, all materials around the detectors were carefully selected for their low radioactivity. Therefore the front end electronic components are placed behind a roman lead shielding above the three detectors. With these precautions combined with the LSM experimental site quality and with the passive shielding surrounding the experiment [16], the gamma ray background is only of $\sim$ 1.5 evts/(keV.kg.day) between 20 and 100 keV, before the gamma rejection. Then residual neutron background is estimated to be 0.03 evts/(kg.day) above 20 keV [12].

2.3 Calibrations

The heat and ionization responses to gamma rays were calibrated using ^{57}Co and ^{137}Cs radioactive sources. A summary of the bolometer baselines, resolutions and energy thresholds can be found in [14].
The simultaneous measurement of both heat and ionization signals provides an excellent event by event discrimination between nuclear and electron recoils. The ratio of the ionization and heat signals depends on the recoiling particle, since a nucleus produces less ionization in crystal than an electron does.
During a ^{252}Cf calibration run, the energy threshold for event by event discrimination can be obtained. Typically with the Edelweiss detectors it is possible to reject more than 99.9 % of electron recoils down to 15 keV. The rejection efficiency is a fundamental parameter for these types of detectors. It is regularly controlled by measuring the ratio of ionization to recoil energy during gamma rays calibrations, where in addition, the charge collection quality for gamma rays can be checked.

3 Latest results

3.1 Ionization trigger

In 2000 and 2002, 11.6 kg.d were recorded with two different detectors [1,9]. In 2003, three new detectors were placed in the cryostat and 20 kg.d were added to the previous published data. The recorded ratio of ionization over recoil energy as a function of recoil energy is represented in Fig. 1. The detectors have a similar behavior compatible to the previous data [1,9].

Three events compatible with nuclear recoils have been recorded. One of them has a recoil energy of about 200 keV, incompatible with a WIMP mass below 1 TeV/c^2. Due to the low statistics, the two other events are used to establish a 90 % C.L. upper limit on the WIMP-nucleon cross section as a function of the WIMP mass, shown in the fig. 2.

With no background subtraction, the new limit is identical to the previous one although it has been obtained with three new detectors and an extended exposure. The Edelweiss experiment has the best published limit for a WIMP mass above 30 GeV/c^2. This result confirms the incompatibility with a C.L. better than 99.8 % with the DAMA candidate [17] with a WIMP mass of about 44 GeV/c^2.

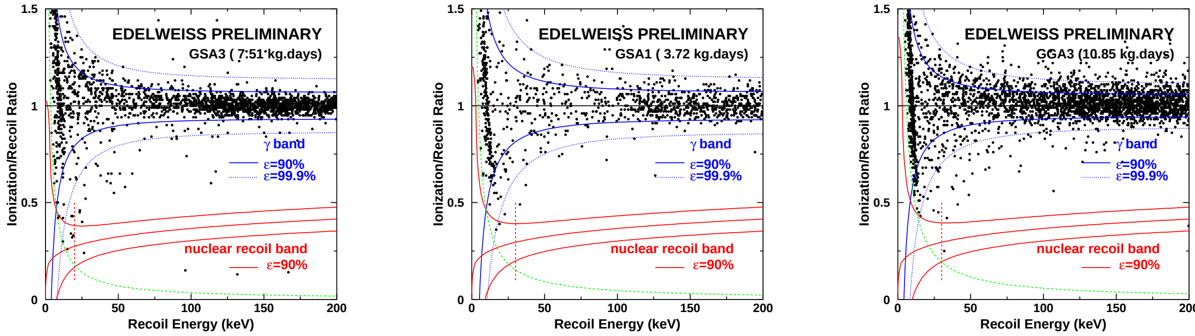

Figure 1: $\frac{E_I}{E_R}$ versus E_R (fiducial volume) for physics runs. The nuclear recoil band is determined by the condition of 90 % acceptance.

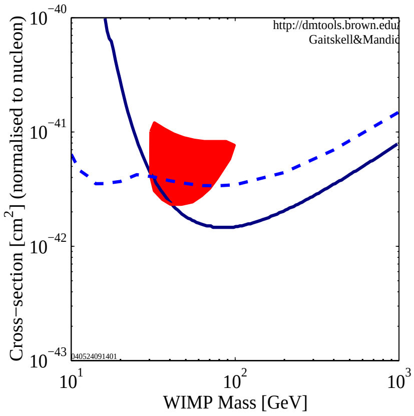

Figure 2: Preliminary exclusion limit (full line) for Edelweiss without background subtraction. Dashed curve : CDMS limit with background subtraction. Closed contour : allowed region at 3σ C.L. from DAMA NaI1-4 annual modulation data.

3.2 Phonon trigger

After these results, the data taking continued with an improved trigger efficiency at low energy. Previously the trigger was the fast ionization signal, now the trigger is the phonon signal. Thanks to a better resolution and no quenching factor on the phonon signal, a 100 % efficiency has been reached down to 10 and 15 keV depending on the detector.
During physics runs, calibrations must be made regularly. A high statistics gamma calibration is realized during the run, in order to check the charge collection quality and test the electron-nuclear recoil discrimination.
A two weeks gamma calibration with a ^{137}Cs source has been made equivalent to about two years of physics run. During this calibration, totalizing about 10^5 events, 31 events (above 10 keV recoil energy) appeared in the nuclear recoil band with some coincïdences between detectors. The corresponding ionization over recoil energy versus recoil energy data are plotted in fig.3.

Nuclear recoil coincïdences observed between the detectors are probably due to neutrons. Such a high background has not been observed in physics runs, this suggests a contamination by a californium source of the cesium source holder. This hypothesis was confirmed by measurements of the source holder in the low background Ge diode setup placed in the LSM. This blind test shows that Edelweiss is indeed sensitive to very low nuclear recoil rates, since detectors are able to discriminate about 30 nuclear recoil events among about 10^5 events. A WIMP with a mass of 52 GeV/c^2 and a cross section with a nucleon of 7.2×10^{-6} pb, would have yielded approximately 20 nuclear recoils in the three months of data taking described in 3.1.

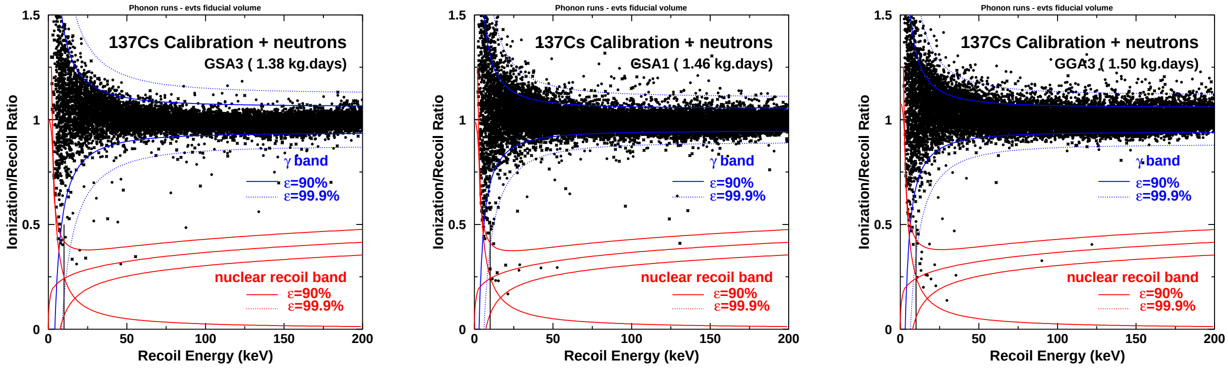

Figure 3: $\frac{E_I}{E_R}$ versus E_R (fiducial volume) for ^{137}Cs calibration runs

4 Edelweiss II

In March 2004, the Edelweiss I experiment has been stopped to allow the installation of the second stage Edelweiss II. The aim is an improvement in sensitivity of a factor 100 and reach most favored SUSY models. A new low radioactivity cryostat (with a capacity of 50 ℓ), able to receive up to 120 detectors, is being tested in the CRTBT laboratory at Grenoble. The first runs will be performed with twenty-one 320 g Ge detectors equipped with NTD heat sensor and seven 400 g Ge detectors with NbSi thin film. With an improved polyethylene and lead shielding and an outer muon veto, the expected sensitivity is $\sim$ 0.002 evt/kg/day.

Note added in proof

During the completion of this paper, new results from the CDMS experiment have been published [18]. They obtained new data with the experiment installed in the Soudan Underground Lab using four Ge and two Si detectors. They improve their previous published sensitivity[6], obtained with the same detectors, by a factor eight .

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